International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249-6890; ISSN (E): 2249-8001
Vol. 8, Issue 2, Apr 2018, 843-850

INVESTIGATION ON PERFORMANCE AND EMISSION BEHAVIOUR OF A SINGLE CYLINDER DIESEL ENGINE FUELED WITH MIXTURE OF COCONUT OIL AND PONGAMIA OIL BIODIESEL BLENDS ALONG WITH DIESEL

D. VIGNESH & L. RAGUNATH

Department of Mechanical Engineering, M. Kumarasamy College of Engineering, Karur, Tamil Nadu, India

ABSTRACT

The major area of research in internal combustion engines is alternative fuels due to the financial crisis in middle east countries, depletion in crude oil resources, hike in fuel prices, and environmental degradation due to harmful exhaust pollutants. The process chosen for conversion of vegetable oil into its methyl ester is transesterification method. In our present work, investigation on performance and emissions have done on single cylinder diesel engine by having the blends of coconut oil methyl ester and pongamia oil methyl ester without doing any further engine modifications. In this study, coconut oil methyl ester addition was kept constant as 5% by volume. Further, both methyl esters were mixed and added to diesel, by volume of 10%, 15%, 20%, 25% and 30%. A comparison between brake thermal efficiency and brake specific fuel consumption has been done for each blend and the readings were compared with pure diesel baseline values. Exhaust emission tests were conducted for detecting the emission levels of unburnt hydrocarbons, carbon monoxide, nitrogen oxides and smoke. A little rise in brake thermal efficiency was observed for lower blends across various loading conditions. Reduction in smoke level and exhaust emission level is observed on the usage of higher biodiesel blends. The final results gave us a clear idea that up to20% biodiesel blend can be very effective in both performance and emission aspects.

***KEYWORDS:** Emission, Transesterification, Pongamiamethyl Ester, Coconut Methyl Ester & Performance*

Received: Feb 21, 2018; **Accepted:** Mar 05, 2018; **Published:** Mar 15, 2018; **Paper Id.:** IJMPERDAPR201896

Original Article

INTRODUCTION

Diesel engines have a huge hope of research as it plays a main role in heavy industrial applications and commercial transportation because of their high fuel efficiency and high torque output. The problem starts with its depleting petroleum fuels and harmful emissions contents [1]. The shortage of petroleum resources took the fuel prices to a high level. So there comes a need for developing an alternative for petroleum fuel. Constant efforts done by various researchers led to the discovery that vegetable oils can be used as a substitute for its properties were matching to diesel [5-6]. Consumption of diesel can be minimized by implementing biodiesel program expeditiously. Biodiesel extraction from various usable and non-usable oils have been found to be a promising fuel for diesel engine. The mainly used sources for biodiesel extraction are pongamia seeds, peanut, and coconut [4]. A certain percent of biodiesel blend with diesel reduce the harmful exhaust emissions by a remarkable percentage. Coconut and pongamia oil are widely grown in Gujarat, Madhya Pradesh,Kerala, Bihar, Tamil Nadu and Punjab in India.

Higher energy content and higher cetane number were the characteristics of bio-diesel blend. Oxidation of exhaust emissions are done due to higher oxygen content in bio-diesel. The first diesel engine had been tested by vegetable oil before opting it with diesel [1]. Atomization of fuel in the combustion chamber is affected due to higher viscosity factor of bio-diesel. This results in more carbon deposits on engine and tendency to coke the injector [7-9].

The production of biodiesel finally takes us to transesterification process, which is frequently preferred for methyl ester extraction from pure vegetable oil, by separating the fat content which regulates the problems associated with viscosity [10-13]. The extracted fat content called glycerine is used in soap industries [3]

NOMENCLATURE

POME	-	Pongamia oil methyl ester
CO_2	-	Caron-di-oxide
COME	-	Coconut oil methyl ester
NO	-	Nitrogen oxides
D	-	Diesel
O_2	-	Oxygen
BTE	-	Brake thermal efficiency
BSFC	-	Brake specific fuel consumption
CO	-	Carbon mono-oxide
HC	-	Hydrocarbon
CV	-	Calorific value

Experimental results show evidence that usage of coconut methyl ester results in slightly lower BTE compared to diesel results but showed a good sign on emission reduction, except NO emission. Only minor research efforts were made on the usage of two biodiesel blends. As coconut methyl ester had a higher viscosity than pongamia methyl ester, its addition was kept constant at 5%.

BIODIESEL PRODUCTION

Coconut oil had been collected by crushing sun- dried fine coconut shells. Pongamia seeds were the source of pongamia oil. The obtained was filtered as it should not have any solid impurities. Figure 1 shows various processes carried out for producing biodiesel.

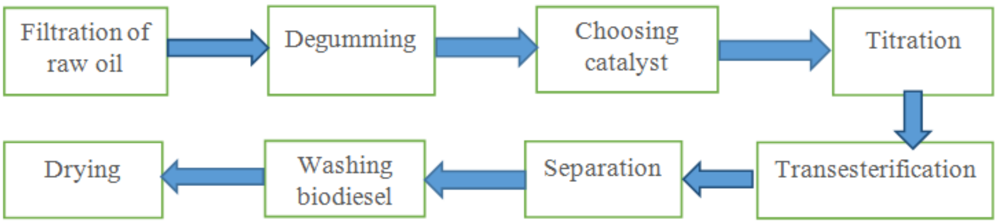
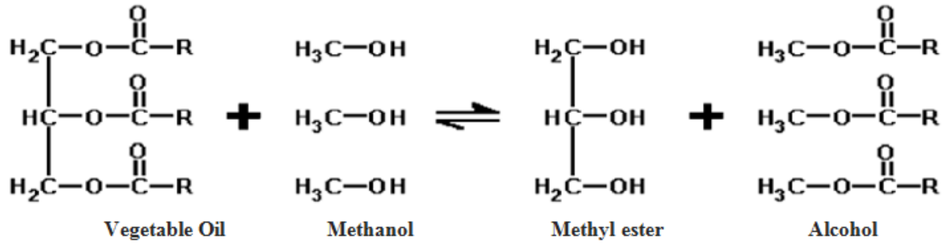


Figure 1: Flow Chart Showing Steps Involved Bio-Diesel Preparation

The filtration technique was carried out by bag filters made of canvas cloth and left for one day for residues to settle. The process of biodiesel preparation has to be carried out in the existence of a catalyst [4]. The choice of catalyst is based on pH value of neat vegetable oil. The pH level of both oils was tested and since both oils have pH value of more than 7, base catalyst (sodium hydroxide) was selected. Improper catalyst selection leads to a lot of soap formation, which is a by-product of trans-esterification process. Titration was carried out to determine the amount of catalyst to be used for the conversion process. In order to separate fat content from the pure oil, a degumming process has been carried out [14]. For this process, sodium hydroxide solution was prepared, where 3.5 grams of sodium hydroxide pellets were dissolved in 100 ml of methanol.

The chemical reaction that occurs during transesterification process is given below,



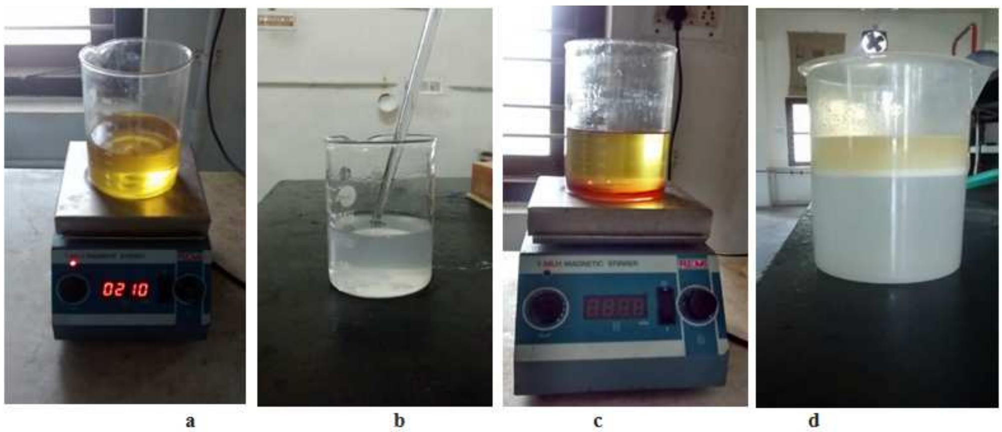


Figure 2: Pictorial Representation of Biodiesel Preparation a, b, c, d (from left to right) a). Heating of Biodiesel in Magnetic Stirrer, b). Preparation of Sodium Hydroxide The solution, c).Trans-esterification Process, d).Washing Biodiesel

A 500 ml of pure coconut oil was taken in a round bottom flask and was heated on magnetic stirrer apparatus, which have a hot plate on the surface. The mixture was stirred at a certain speed and was taken to a temperature of 70°C [1]. After that, the prepared sodium hydroxide solution was poured slowly into the heated oil in the flask and constantly stirred. The mixture in the flask has been maintained at a temperature of 65°C to 80°C for at least 3 hours with help of magnetic stirrer arrangement. The flask was taken away from the stirrer setup and kept separately for 24 hours which made the hydratable portions to accumulate, which becomes heavy and settle at the bottom of the flask, while oil being light floatingg on the top due to the difference in their specific gravities [1].

The two products formed are methyl ester of the oil and glycerine. The two products were separated and washing of biodiesel had been done to remove catalyst, unreacted alcohol, and furthermore glycerine from the biodiesel [3]. Washing process was carried out three times to obtain the neat biodiesel with the help of separating funnel, which uses gravity phenomenon as its principle [14]. Only distilled water has been used for washing purpose. The final product of this

process was pure biodiesel. Even though it was pure biodiesel, it had some moisture content in it which has to be removed otherwise it will lead to corrosion in the engine parts. The prepared biodiesel was heated to around 1050°C in vacuum state for a time period of 3 hours to remove the residual moisture contained in the final biodiesel [4]

EXPERIMENTAL SETUP

A naturally aspirated single cylinder agricultural diesel engine was nominated for this research. Table 1 shows the engine's key specifications.

Table 1: Specifications of Chosen Diesel Engine

Make	Field Marshall
Type	Four- stroke
Displacement	1433CC
Rated power	7.35kW
Rated speed	1000rpm
Stroke	139mm
Bore	114mm

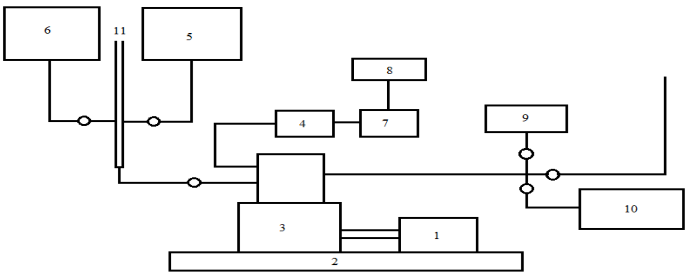


Figure 3: Experimental Setup - Skeleton Diagram

1. Rope Brake Dynamometer, 2. Engine Test Bed, 3. Engine, 4. Air Filter, 5. Bio-Diesel Tank, 6. Diesel Tank, 7. Airbox, 8. Manometer, 9. Smoke meter, 10. Exhaust gas analyzer, 11. Burette

The taken engine was fitted with needed instrumentation which is shown in figure 3 and the required tests were performed. As blends were used two fuel tanks were fitted, one for pure diesel and another one for biodiesel. Prony brake dynamometer had been used to apply different load on the engine. The exhaust gas analyzer used was HORIBA make (model- MEXA-584L), which measures HC, NO in parts per million (ppm) and CO in percentage volume (% vol). AVL smoke meter was used to measure smoke density, which measures smoke in percentage volume (% vol).

Firstly, an engine was cranked at no load condition and allowed to run for 20 minutes on neat diesel to attain the steady state. The performance, emission, and smoke data are noted which was used as reference value for comparing. Time for 10ml consumption of fuel was noted, which was the major data in computing performance. Testing was done at constant speed (1000 rpm) and varying load mode. Each time, a load was incremented by 2.5 kg (starting from no load to a maximum of 12.5 kg)

BLEND RATIOS AND ITS PROPERTIES

The prepared biodiesel was blended with neat diesel at the belowmentioned percentages for testing the engine performance and emissions. The blend ratios were given in Table 2.

Table 2: Blend Name and its Ratios

Blend Name	Blend ratio
B10	5% POME, 5% COME and 90% D
B15	10% POME, 5% COME and 85% D
B20	15% POME, 5% COME and 80% D
B25	20% POME, 5% COME and 75% D
B30	25% POME, 5% COME and 70% D

The blends were prepared correctly by using calibrated beakers otherwise the ratio won't be proper which affects the entire results. The coconut oil methyl ester addition was kept as constant as 5% by volume and only pongamia oil methyl ester addition was varied because of its higher density and calorific value.

Table 3: Properties of Blends

SI. No	Property	B10	B15	B20	B25	B30
1	Density (kg/m³)	818.8	819.8	821.5	823.2	824.9
2	Flash point (°C)	47.95	49.75	51.55	53.35	55.15
3	Fire point (°C)	53.65	55.80	57.95	60.10	62.25
4	CV (MJ/kg)	44.994	44.747	44.500	44.253	44.006
5	Kinematic viscosity (mm²/s)	3.17	3.277	3.32	3.37	3.42

The properties such as density, viscosity, flash point, fire point and calorific value vary for each blend which is mentioned in Table 3. For higher blends, density and viscosity keep on increasing while the energy content available in the blend decreases.

Density was calculated by a known technique, which is mass of liquid divided by its volume. Calorific value was calculated by bomb calorimeter apparatus. Flashpoint and fire point keep on increasing with higher blends as biodiesel has less firing capability when compared to neat diesel. Viscosity had been measured by redwood viscometer, where resistance to fluid flow was measured in terms of mm²/s. If viscosity and density of fuel are high, it affects the flow properties and fuel atomization in the combustion chamber, which eventually affects the performance and emission values.

RESULTS AND DISCUSSIONS

Performance

Diesel engines deliver high torque and power output hence play a major role in commercial vehicle segment. The main parameters considered here are brake thermal efficiency and brake specific fuel consumption. BTE can be defined as the brake power of an engine as the function thermal input from fuel. BSFC looks at engine's fuel efficiency and is calculated by dividing fuel consumption by brake power.

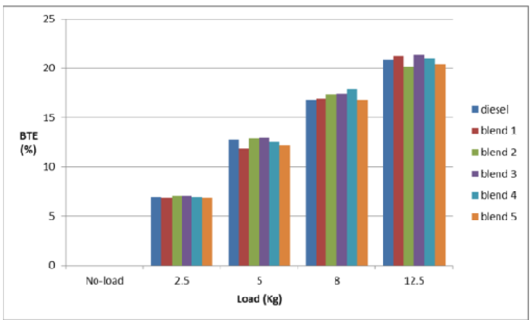


Figure 4: BTE vs Load Graph

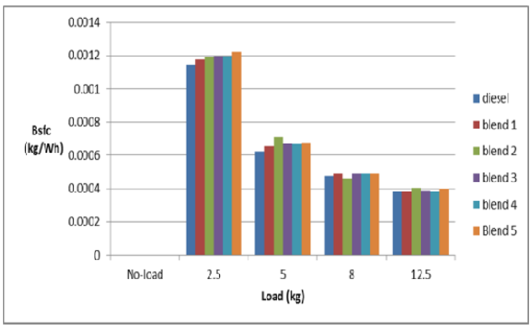


Figure 5: BSFC vs Load Graph

From figure 4, it was observed that brake thermal efficiency of biodiesel blends shows an increasing trend when compared with diesel fuel. An increase in brake thermal efficiency was observed for blend-3 (15% POME, 5% COME and 80% D) in all loads because of extra oxygen available and greater cetane value. High cetane value improves ignition quality of fuel and supports for complete combustion. From figure 5, it was detected that BSFC for blends rises marginally than diesel owing to lesser energy content in biodiesel. BSFC of blend-3 (15% POME, 5% COME and 80% D) seemed comparable to diesel at higher engine load.

EXHAUST EMISSION

The harmful pollutants from diesel engines are CO, HC, NO_X and particulate matter. Exhaust gas analyzer (HORIBA MEXA-584L) was allowed to warm up for 300 seconds and after that leak test, HC hang- up test was carried out to ensure its proper functioning. After these tests, analyzer became fully functional and ready to measure the emission values. Exhaust gas analyzer probe was introduced into the exhaust pipe to measure the emission data. Smoke meter measures the smoke values precisely only if the heater temperature is between 70^0C to 80^0C. Firstly, the engine was allowed to run on diesel fuel until steady state was achieved and emissions values were taken. Engine steady state was attained for each blend before taking emission values and the results were compared with baseline diesel values.

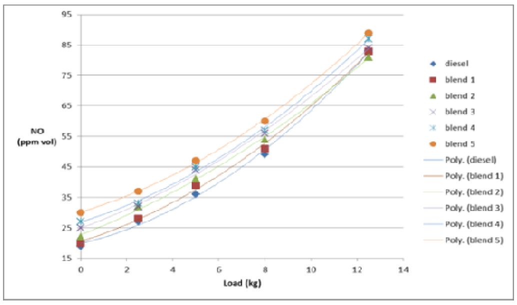


Figure 6: Load vs NO Emission

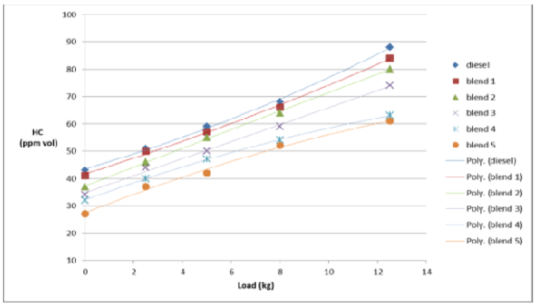


Figure 7: Load vs HC Emission

From figure 6, it was observed that 10% increase in NO emission for each higher blend starting from blend-1 because of high oxygen content in blends, which made the combustion chamber temperature to shoot up. Nitrogen pools with oxygen to form NO, only if the combustion chamber temperature is sufficiently high. From figure 7, it was observed that HC emission decreases by 20% by the use of blends and at high loads, HC reduction rate was high (about 45%) as blends have high oxygen content, which supports better and stable combustion.

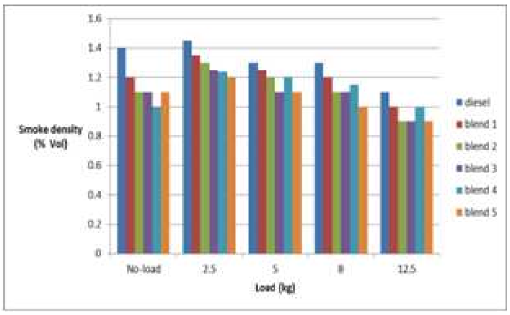


Figure 8: Load vs Smoke Density

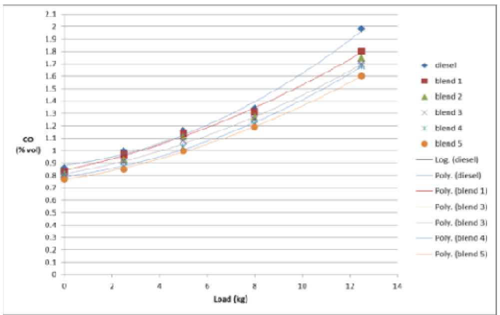


Figure 9: Load vs CO Emission

From figure 8, it was observed that smoke density decreases by 30% by the usage biodiesel blends.

This reduction in smoke was due to more stable and complete combustion occurrence owing to more quantity of

oxygen in blends. Blend-5 shows a higher reduction in smoke density. The reduction in smoke is up to certain percent of the blend. At very high blends, smoke increases due to improper combustion due to higher density and viscosity reasons. From figure 9, it was observed that carbon monoxide formation was reduced by 20% by the use of biodiesel blends. The main reason for CO formation is due insufficient oxygen. As biodiesel have a higher content of oxygen, the excess oxygen available will combine with CO and oxidize it to CO_2. At higher loads and blends, the decrease in CO rate was observed higher.

CONCLUSIONS

The experimental results obtained showed that the use of biodiesel blends reduce the performance of engine as blends had lower calorific value. In performance wise, blend-3 (5% COME, 15% POME, and 80% D) showed 10% increase in brake thermal efficiency on all operated loads comparing to baseline values of diesel. The SFC increases for blends because of their lesser energy content and increasing densities. Smoke opacity decreases by 30% for all the blends due to stable and complete combustion, as biodiesels are richer in oxygen content. The emission results showed that HC emission reduces for all the blends and particularly blend-5showed 35% reduction when compared with baseline diesel emissions due to complete combustion as blends have high oxygen content. NO emission increases by 10% for each higher blend than the previous lower blend, starting from B10. A 50% increase in NO emission was observed for B30 when compared with baseline diesel emission values. Results proved that lower blends, particularly B20(5% COME, 15% POME, and 80% D) can be used for obtaining better performance and emission values.

REFERENCES

1. *Ramadhas AS, Muraleedharan C, Jayaraj S. Performance and emission evaluation of a diesel engine fueled with methyl esters of rubber seed oil. Renewable Energy 2005;30:1789-1800*
2. *Manu Ravuri, Rajasekhar Reddy M, HarshaVardhan D, Mohammed Muzahid K. Performance investigation of DI-Diesel engine with combined neem and pongamia oil blends. JAET*
3. *Vinukumar K. Production of biodiesel used in diesel engines. IJET*
4. *Sahoo PK, Das LM, Babu MKG, Naik SN.Biodiesel development from high acid value polanga seed oil and performance evaluation in a CI engine*
5. *Goering CE, Schwab AW, Daugherty MJ, Pryde EH, Heakin AJ, Fuel properties of eleven vegetable oils, Trans. ASAE 25 (6) (1982) 1472–1477.*
6. *V.Sriram et al.,, Engine Performance and Emission Characteristics of 1-Octanol Blended Bio-Diesel in a Single Cylinder Diesel Engine, International Journal of Mechanical and Production Engineering Research and Development (IJMPERD), Volume 7, Issue 6, November - December 2017, pp. 623-630*
7. *M.O. Bagby, B. Freedman, and A.W. Schwab, Seed oils for diesel fuels: sources properties, ASAE Paper, Paper Number 871583, 1987.*
8. *R.A. Korus, T.L. Moursetis, L. Lloyd, Polymerization of vegetable oils. In vegetable oil fuel, in: Proceedings of the International Conference on Plant and Vegetable Oils as Fuels, St. Joseph, MI, USA, 1982, pp. 218–223.*
9. *A.N. Van Der Walt, F.J.C. Hugo, Attempts to prevent injection coking with pongamia oil by engine modification and fuel additives. In vegetable oils fuel, in: Proceedings of the International Conference on Plant and Vegetable Oils as Fuels, St. Joseph, MI, USA, 1982, pp. 230–238.*

10. *G. Velgutth, Performance of vegetable oil and their monsters as fuels for diesel engines, SAE Paper 1983: Paper Number 831358.*
11. *S.J. Clark, L. Wagner, M.D. Schrock, P.G. Piennar, Methyl and ethyl soybean esters as renewable fuels for diesel engines, JAOCS 61 (10) (1984) 1632–1638.*
12. *Vignesh.C,.Prasanna "Effect of constructional change in I.C engine piston by partially ceramic coating" Pakistan Journal of Biotechnology Vol. 14 special issue Pp. 116- 119 (2017)*
13. *L.A. Perkins, C.L. Peterson, Durability testing transesterified winter rape oil (Brassica napus L.) as fuel in small bore, multi-cylinder DI diesel engines, SAE Paper, Paper Number 911764, 1991.*
14. *Q.M. Zhang Felderman, C.L. Peterson, Diesel engine durability when fuelled with methyl ester of winter rapeseed oil, ASAE Paper, Paper Number 881562, 1988.*
15. *Karthe. M, Prasanna.S.C "Investigations on the emission characteristics of diesel engine blende with isopropyl alcohol" Pakistan Journal of Biotechnology Vol. 14 special issue Pp. 160 - 163 (2017)*
16. *Vignesh.D, Srihari.S, Investigation on performance and emission behaviour of a single cylinder diesel engine fuelled with mixture of cottonseed and sunflower biodiesel blends along with diesel. International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 19 (2015) pp 40265-40269*
17. *M.N. Pestes, J. Stanislao, Piston ring deposits when using vegetable oil as a fuel, Journal of Testing and Evaluation 12 (2) (1984) 61–68*